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# STATEWIDE SURVEY OF AIR POLLUTION DAMAGE TO VEGETATION, 1969

Pennsylvania State University
Univsity Park, Pennsylvania

January 1970

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## THE CENTER FOR AIR ENVIRONMENT STUDIES

The Center for Air Environment Studies at The Pennsylvania State University was established in 1963 to coordinate research and instruction concerning the interaction of man and his air environment. A unit of the interdisciplinary Institute for Science and Engineering, the Center has a staff with backgrounds in many of the physical, biological, social, and allied sciences.

A broad, flexible research program, dependent on faculty and student interest, is maintained by the Center. Some of the current research topics are:

The operation of an air pollution information service utilizing computers and other mechanized systems for the collection, retrieval, and dissemination of air environment literature. "Air Pollution Titles" and "Index to Air Pollution Research," information retrieval periodicals, are produced using computers. (See inside back cover.)

Effects of air pollutants on trees, food, and fiber crops, predisposition to attack by other pathogens, and economic loss through damage to plants.

Studies of small particle behavior.

Development of high accuracy, low cost mobile analysis equipment for routine sampling of ambient air.

Biological effects of air pollutants on animals and natural ecologies.

Studies of basic combustion processes leading to lower contaminant emissions.

A survey of community attitudes toward air pollution.

The description and analysis of the political, legal, and administrative systems for air pollution control through studies in Pennsylvania, New York, and the Delaware Valley.

Study of plume rise and dispersion with analysis of contaminant concentration in the plume.

Development of rapid response, specialized instrumentation for the quantitative measurement of contaminant concentration.

Special studies of gaseous and particulate control devices.

Controlled atmosphere air quality studies for a life-support system.

Fundamental research on the chemistry of airborne contaminants.

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continued on inside back cover

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# STATEWIDE SURVEY OF AIR POLLUTION DAMAGE TO VEGETATION -- 1969

January 1970

COLOR ILLUSTRATIONS REPRODUCED IN BLACK AND WHITE

Center for Air Environment Studies
Dr. William J. Moroz, Director
The Pennsylvania State University
University Park, Pennsylvania

CAES Publication Number 148-70

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## FORWARD

The survey represents a first attempt to identify and assess economic losses to vegetation due to air pollution in the Commonwealth of Pennsylvania and was conducted with the assistance of county agricultural agents and extension specialists. The project was initiated in response to a request from the Pennsylvania Department of Agriculture for information concerning agricultural losses due to air pollution. This report was prepared by T. Craig Weidensaul, Ph.D., and Norman L. Lacasse, Ph.D.

## ACKNOWLEDGEMENTS

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Cooperating agencies and departments are as follows:

Pennsylvania Department of Agriculture

Pennsylvania Department of Health, Bureau of Air Pollution Control

Pennsylvania Department of Forests and Waters

Cooperative Extension Service

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Department of Plant Pathology, The Pennsylvania State University

Center for Air Environment Studies (CAES), The Pennsylvania State University

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## ABSTRACT

During the summer of 1969, a statewide survey of air pollution damage to vegetation was conducted to assess economic losses incurred on food and fiber crops in Pennsylvania. Ninety-two investigations were made in 28 counties. Most incidents occurred in areas of greatest agricultural activity. Greatest economic losses were observed on vegetable, fruit, and agronomic crops, followed by lawns, ornamentals, greenhouse flowers, and forest trees. The suspected major pollutants in decreasing order of importance are: oxidants, oxides of sulfur, lead, hydrogen chloride, particulates, herbicides, and ethylene. The total amount of direct economic loss was estimated to be in excess of 3.5 million dollars. Indirect economic losses accounted for an additional 8 million dollars. These losses include known profit losses to growers, costs of reforestation of denuded areas, known grower relocation costs, and substitution of lower value crops for higher value crops. Other unassessed indirect losses observed are destruction of aesthetic values, erosion, stream silting, damage to watershed retention capacity, and farm abandonment.

# INTRODUCTION

## Agriculture and Forestry in Pennsylvania

The importance of the agricultural and forest industries in Pennsylvania must not be underemphasized. The agricultural industry in the State accounts for over one billion dollars in cash receipts to growers each year while the added value from processing is 4 billion dollars. The yearly values of field and forage crops, vegetables, and fruits and maple syrup in Pennsylvania are $295 million, $22 million, and $27 million, respectively. The principal agricultural crops, ranked by value of production in the Commonwealth, are hay, corn, mushrooms, potatoes, oats, apples, wheat, cut flowers, tobacco, and barley. Table 1 shows a breakdown of values for various crops.

Pennsylvania is the leading cut-flower producing State in the Northeast and ranks third nationally in this category. This industry, based on wholesale prices, is valued at nearly 13 million dollars annually. This State ranks second in rose production, third in carnations, third in pom pom chrysanthemums, and fourth in standard chrysanthemums.

Nationally, Pennsylvania ranks first in mushroom production, third in cut flowers, fourth in maple syrup, fourth in grapes, third in tart cherries, ninth in sweet cherries, fourth in clover-timothy hay, twelfth in all hay production, fifth and seventh in timothy and red clover seed production, respectively, seventh in tobacco, fifth in peaches, sixth in apples, eighth in pears, eighth in oats, and eleventh in the production of processing vegetables.

Pennsylvania ranks in the top five states in milk production and in most categories of manufactured dairy products. Milk production alone accounts for $409 million. An annual inventory of some 2.5 million livestock animals is valued at more than $441 million. Pennsylvania ranks second and third, respectively, in cash receipts from farm chickens and eggs.

Table 1. Crop Values in Pennsylvania

| Crop | Value/year [1] $ millions |
|---|---|
| Hay and Silage | 159.3 |
| Grains | 105.2 |
| Mushrooms | 37.7 |
| Fruits and Maple Syrup | 27.0 |
| Vegetables | 22.0 |
| Potatoes | 19.7 |
| Cut Flowers | 12.8 |
| Tobacco | 10.6 |
| TOTAL | 394.3 |

1/ Based on 1967 statistics

Pennsylvania, occupying land area in excess of 28.8 million acres, has 37 percent of its total land area occupied by farms and 58 percent of its land area covered by forests. Nearly 17 million acres are classified as commercial forests and only two counties, Philadelphia and Delaware, have no commercial forest land.

Between 1954 and 1964 there was an increase of six percent in commercial forest land area in the State. Pennsylvania's commercial forest land is classified by ownership in Table 2.

Table 2. Ownership of Commercial Forest Land

| Ownership | Percent of Total Commercial Forest Land |
|---|---|
| State forest lands | 10 |
| State game lands | 6 |
| National forest | 3 |
| Forest Industry | 4 |
| Farm owned | 15 |
| Other | 62 |
| TOTAL | 100 |

In 1964, there was a forest growing stock of 17,860.6 million cubic feet, 91.7 percent of which was hardwoods. There was also a sawtimber inventory of 26,268.7 million board feet, 87.6 percent being hardwoods. The pole timber inventory was set at 113.8 million cords, 93.6 percent of which was hardwoods. There are approximately 1,000 tree farms in the State.

Although primarily a manufacturing State, Pennsylvania ranks sixteenth nationally in total lumber production and second in hardwood production. The Commonwealth's woodlands produce 6.6 percent of the nation's hardwoods and 1.4 percent of all timber harvested in the country. Over two million tons of paper and paperboard are produced in the State each year.

Over 1.5 million people are employed in wood manufacturing industries in the State. This number accounts for 5.8 percent of the total manufactural employment. The value added to lumber and wood products in Pennsylvania due to manufacturing alone is nearly one billion dollars.

The total value of the forest industry in Pennsylvania exceeds $855 million per year. This amount is slightly more than five percent of the total of all manufacturing in the State.

From the figures presented, it should be obvious that Pennsylvania's agriculture and forestry are valuable assets and certainly justify proper management and protection.

Not only are these assets valuable by monetary standards, but by aesthetic standards as well. Pennsylvania's agricultural and forest lands are a prime factor in attracting tourists and must be conserved to assure protection of watersheds used for recreational purposes and water supply.

Statistics show that the demand for certain forest products will increase greatly in the years to come. Agricultural management is becoming more intensive as land is gradually removed from agricultural production, and the productivity of land increases.

Efforts to increase our productivity in agriculture and forestry without giving serious consideration to those factors which limit production may result in decreased or lowered productivity. Problems relating to the environment will probably assume greater importance in crop production in the near future because of urban and industrial expansion into rural areas. Unless serious efforts are made immediately to deal with these problems, the Commonwealth of Pennsylvania may well experience a detrimental shift in agricultural production.

## PURPOSE, SCOPE, AND OBJECTIVES OF SURVEY

For several years speculative estimates were the only source of figures available for vegetation damage and health impairment caused by air pollutants. Some individuals unrealistically magnified their estimates for one reason or another while others tended to pass off air pollution damage as either insignificant and unimportant or as a necessary by-product of technological progress which we could discount as being relatively harmless.

As mentioned previously, Pennsylvania ranks rather high in agricultural and forest industries. Some well-founded thought prompted Pennsylvania legislators and agricultural administrators to raise questions concerning the effects of air pollution on the agricultural industry in the State. The only information available was the speculation of interested and concerned individuals which could not be substantiated by any published research or survey data. Not only were such data lacking for Pennsylvania but for most other states as well. This situation led to the organization and implementation of a survey designed to assess the economic effects of air pollution on vegetation in Pennsylvania and to estimate the annual losses in food and fiber production in the Commonwealth in more realistic figures. Once such figures are established the needs for research can be more clearly defined and solutions sought.

Both commercially and noncommercially produced cultivated and noncultivated plants were studied. Special emphasis, however, was placed on agronomic crops (field, forage, tobacco and potatoes), fruits and vegetables, forests, lawns and shrubs, glasshouse and nursery plants, and outdoor herbaceous and woody ornamentals. Non-cultivated weed species were also examined, particularly around suspected sources where either cultivated crops had never been grown or where crop production had been discontinued.

The area to be surveyed included all 67 counties with emphasis placed on those counties having large urban and industrial centers. The county agricultural agents in each county reported any air pollution episodes and possible plant damage to the Center for Air Environment Studies at The Pennsylvania State University. By soliciting the help of county agents and University extension specialists, it was thought constant surveillance might be maintained and more complete and reliable survey results obtained.

The survey was conducted and the data summarized and reported by CAES personnel. Monthly progress reports were distributed to members of cooperating agencies.

## SURVEY METHODS

The success of the survey depended on the participation of the county agricultural agents and extension specialists. The survey was designed to achieve maximum coverage of the state. To accomplish this goal, it was necessary to utilize existing manpower. Before the survey was initiated, a 3-day training program was conducted at The Pennsylvania State University to acquaint the county agents or their representatives with symptoms of pollution damage as well as sources of pollutants.

A comprehensive handbook of effects assessment of vegetation damage, edited by N. L. Lacasse and W. J. Moroz, was distributed to all who registered at the training conference. The handbook, designed to aid the diagnostician in identifying damage from pollutants, is composed of papers presented by guest lecturers on the subjects of sources of pollution, meteorological factors, oxidants (ozone, peroxyacetyl nitrate, nitrogen dioxide) and mimicking symptoms, particulates, agricultural chemicals, salinity and other chemicals, fluorides and mimicking symptoms, sulfur dioxide and mimicking symptoms, other air pollutants and mimicking symptoms, and methods of assessing air pollution injury. The handbook also contains many color plates showing characteristic plant damage symptoms.

Printed report forms were distributed to county agents' offices and to personnel of the Pennsylvania Department of Health, the Pennsylvania Department of Forests and Waters, and the Pennsylvania Department of Agriculture (Figure 1).

Figure 1. Form for Reporting Air Pollution Injury to Plants

AIR POLLUTION INJURY REPORT

Request Assistance _____ County _____

Grower Identification _____

Location of Observation _____

Suspected Pollutant: $SO_2$, $O_X$, F, other (Specify) _____

Crop & Variety _____

Acreage Affected _____ or No. of Plants _____

Date of Incidence _____

---

Avg. % of Each Plant Affected: 0-10, 11-30, 31-60, 61-80, 81-90, 91-99, 100

Avg. % of Plants Affected: 0-10, 11-30, 31-60, 61-80, 81-90, 91-99, 100

Loss in (check one): Quality _____ Quantity _____

Estimated Crop Loss: _____ % or $ _____

Remarks _____

_____

_____

Date _____ Reporter's Name _____

_____

Damage reports were first received in May, 1969 at which time field investigations and verification of damage began. Reports of damage were not restricted to injury which occurred only during 1969 since many episodes are continuing. An effort was made to investigate past episodes for the purposes of detecting possible trends and determining the proportion of the total damage observed in one year (1969).

Many reports were submitted by concerned individuals other than those who were directly involved in the survey. A news release was prepared by the Cooperative Extension Service prior to the initiation of field activities and appeared in many newspapers across the State. Initial reports of possible vegetation damage were directed to the county agents' offices and were subsequently forwarded to the Center for Air Environment Studies if air pollution damage was suspected.

Many cases of air pollution damage to vegetation were uncovered through conversations with county agents and growers. Such cases represented long-standing problems which had been taken for granted.

The CAES survey staff made systematic examinations of greenhouses and nurseries across the State. Various types of vegetation around known and/or suspected pollution sources in industrialized and urban areas as well as near isolated sources in rural areas were checked.

Identification of the suspected pollutant was based solely on symptom expression. A knowledge of the chemical, cultural, and environmental influences experienced by the vegetation in question was taken into consideration.

Most research and screening of plants for their sensitivity to various pollutants has involved relatively few species of plants. Atypical symptoms or symptoms not previously described were encountered in a few cases. However, plant damage was observed following atmospheric inversions and no damage from other plant diseases or cultural mistreatment could be implicated.

Monthly progress reports were prepared indicating the nature of plant damage, the crop plants on which damage was observed, and the counties in which plant injury occurred.

Estimates of economic losses were based on crop value and production costs incurred by harvest time. Consideration was therefore given to recovery of the crop following fumigation.

For the purpose of this survey, direct losses to producers or growers include only production costs, i.e., the value of the crop at the time damage occurred. If the crop was not completely damaged, the loss reported reflected only that portion of the crop affected, i.e., reduction in yield quantity and/or quality, cost of cleaning the produce, etc. Therefore, as best as could be determined, grower profits normally included in market prices were not included under direct losses.

However, in assessing the value of damaged standing timber, for example, market stumpage prices were used as the basis for losses since production costs could not be determined on unmanaged forest land. Damage to woody ornamentals was assessed according to the guidelines established by the National Shade Tree Conference. However, unless the plants were permanently damaged by at least 50%, losses were determined according to the proportion of the plant affected. Losses involving permanent lawn damage were based on replacement costs.

The reason for including only production costs under direct losses is based on the fact that profit losses cannot be recovered through most litigation procedures.

For the purpose of this survey, indirect losses are meant to include known profit losses, i.e., the difference between market values and production costs, cost of reforestation of denuded areas, known grower relocation costs, and substitution of lower value crops for higher value crops. In addition, there are other indirect losses which were observed, but which could not be assessed. Examples of these are: destruction of aesthetic values, erosion, stream silting, damage to watershed retention capacity, and farm abandonment.

At the completion of the field season, a questionnaire was prepared and distributed to the county agricultural extension agents for their comments and evaluation of training, survey methods, field investigations, and communication.

## RESULTS OF SURVEY

Between May 1 and November 1, 92 field investigations were made in 28 counties (Table 3). All investigations, whether in response to a report or if by independent examination by CAES personnel, did not always reveal pollution-caused vegetation damage. Of these, 60 investigations revealed damage which was attributed directly to air pollution. Damage resulting from pollution was observed in 23 counties located primarily in southeastern and western Pennsylvania.

Twenty-four reports were submitted by county agricultural extension offices, nine reports from University extension specialists, and five reports from the Pennsylvania Department of Forests and Waters.

Pollution damage was observed on a wide range of plants (Table 5). Vegetation is categorized into either commercially-or non-commercially-produced plants. Agricultural and forest statistics are usually based on commercial production for profit, not on individual or home grown production for personal consumption. Economic losses incurred on home garden plants and flowers are very difficult to assess. Little emphasis was placed on these crops during this first year of the statewide survey, but in future years, more attention should be devoted to these plants. In many cases of vegetation damage economic losses did not result, but weed species and other relatively unimportant vegetation served as good indicators of pollution problems should any of these areas be used for crop production in the future. The crops affected by various pollutants are summarized by county in Table 6.

Based on data aquired during 1969, some of which pertains to incidents that occurred during the last 2 or 3 years, vegetables, fruits, and agronomic crops appear to be the most seriously affected, collectively accounting for over 3.2 million dollars in direct losses. Lawns, shrubs, and woody ornamentals together suffered severe injury and resulted in over 200 thousand dollars in losses (Tables 7 & 8). Timber losses in excess of 39 thousand dollars were realized and over 56 thousand dollars in damage occurred on commercial flowers and foliage plants. It must be emphasized that economic losses presented in Tables 7 and 8 are quite conservative and encompass only losses in plant damage, not grower profits or losses to related industries.

Table 3. Summary of Vegetation Damage Reports by Agency

| Agency | Number of Reports |
|---|---|
| County Agricultural Extension Offices | 24 |
| University Extension Specialists | 9 |
| Penna. Dept. of Forests and Waters | 5 |
| Independent Visits by CAES Staff | 54 |
| Total Number of Investigations | 92 |
| Number of Counties Visited | 28 |

The total amount of damage uncovered through the survey was estimated to be in excess of 3.5 million dollars. Certain sources which contributed to the damage have now been eliminated. In some cases the production of sensitive crops near continuing sources has been discontinued.

However, based on information obtained from the county agents, several incidents of air pollution damage to vegetation were not reported to the survey staff. Furthermore, three of the cases investigated resulted from accidental acute fumigations and are not expected to recur. Also, no additional damage will occur near discontinued sources and where production of sensitive crops has been discontinued. Consequently, the estimated loss reported for 1969 probably does not represent continuing annual losses. A more realistic annual loss would probably approach 2.5 million dollars.

The losses to vegetable crops attributed to oxidants in the Delaware Valley area represent about 83% of total losses reported. It should be recognized that southeastern Pennsylvania represents the best farm land in the Commonwealth and consequently, agricultural production is greater than in any other area of the State. Although very sensitive crops can no longer be grown profitably in that region, damage to other cash crops from oxidants is expected to continue with increased urban and industrial expansion. Oxidant damage to ornamental plants and shade trees is also expected to increase.

Based on the results of the survey, the suspected major pollutants in the Commonwealth, based on associated economic losses, appear to be (in decreasing order of importance) oxidants, oxides of sulfur, lead, hydrogen chloride, particulates, herbicides, and ethylene.

Table 4. Summary of Vegetation Damage Reports by County

| County | Number of Reports Investigated | County | Number of Reports Investigated |
|---|---|---|---|
| Allegheny | 7 | Indiana | 5 |
| Armstrong | 7 | Jefferson | 1 |
| Beaver | 3 | Lancaster | 7 |
| Berks | 4 | Lebanon | 3 |
| Bucks | 4 | McKean | 2 |
| Butler | 5 | Mifflin | 2 |
| Cambria | 4 | Montgomery | 4 |
| Carbon | 2 | Philadelphia | 2 |
| Centre | 4 | Schuylkill | 1 |
| Chester | 8 | Susquehanna | 1 |
| Clearfield | 3 | Venango | 3 |
| Columbia | 2 | Westmoreland | 1 |
| Elk | 2 | Wyoming | 1 |
| Erie | 3 | York | 1 |

Table 5. List of Plants Affected

Agronomic Crops (commercial)

Alfalfa
Barley
Clover
Corn
Grasses (Pasture)
Oats
Rye
Tobacco
Timothy
Wheat

Vegetables and Fruits (commercial)

Beet (Red)
Beet (Sugar)
Broccoli
Corn (Sweet)
Endive
Greens
Lettuce (Leaf)
Onions
Peppers (Sweet)
Spinach
Swiss Chard
Tomatoes

Vegetables and Fruits (non-commercial)

Apple
Beans (Green)
Beets (Red)
Broccoli
Cherry
Corn (Sweet)
Cucumbers
Grapes
Okra
Peach
Pear
Peppers (Hot)
Peppers (Sweet)
Plum
Pumpkin
Rhubarb
Squash

Trees (commercial Forest-Timber)

Ash (White)
Basswood
Beech (American)
Birch (Yellow)
Birch (Sweet)
Cherry (Black)
Dogwood
Hickory
Maple (Red)
Maple (Sugar)
Oak (Black)
Oak (Red)
Oak (White)
Sassafras
Yellow-poplar

Table 5. List of Plants Affected (continued)

Trees
(commercial Christmas)

Fir (Fraser)
Pine (Austrian)
Pine (Scotch)

Trees
(Shade, ornamental, spoil banks-non-comercial)

Ash (White)
Basswood
Catalpa
Cedar
Cherry
Cottonwood
Dogwood
Douglas-Fir
Elm (American)
Elm (Chinese)
Flowering Crab
Ginkgo
Hawthorn
Hemlock
Holly (American)
Larch
Lilac
Maple (Norway)
Maple (Red)
Maple (Sugar)
Mulberry
Oak (Red)
Olive (Russian)
Pine (Red)
Pine (Scotch)
Pine (White)
Spruce (Blue)
Spruce (Norway)
Sycamore
Tree of Heaven
Walnut (Black)

Flowers (commercial)

Carnations
Chrysanthemums (pom pom)
Chrysanthemums (potted)
Daisies
Geraniums
Lily (Easter)
Orchids
Pansies
Petunias
Poinsettias
Roses
Snapdragons

Flowers (non-commercial)

Azalea
Browallia
Dahlia
Petunia
Roses
Zinnia

Lawn and Shrubbery

Arborvitae
Boxwood
Hedge (Privet)
Holly (Bush)
Juniper
Lawn (Blue Grass)
Rhododendron
Yew

Table 5. List of Plants Affected (continued)

Cover and Weed Species

Bedstraw
Blackberry
Burdock
Chickweed
Crownvetch
Dandelion
Dewberry
Fern
Goldenrod
Grasses
Greenbrier
Lambsquarters
Maple (Striped)
Raspberry
Viburnum spp.
Sassafras
Spicewood

## CODE FOR AFFECTED CROPS

| | Code Number |
|---|---|
| Agronomic Crops (includes forage and tobacco) | 1 |
| Vegetables and Fruits (commercial) | 2 |
| Vegetables and Fruits (non-commercial) | 3 |
| Trees (Forest-Timber) | 4 |
| Trees (Christmas) | 5 |
| Trees (shade, ornamental and spoil bank plantings) | 6 |
| Flowers and Foliage Plants (commercial) | 7 |
| Flowers and Foliage Plants (non-commercial) | 8 |
| Lawns and Shrubs | 9 |
| Cover and Weed Species | 0 |

Table 6. List of Crops Affected by County and Characteristic Pollutant Type

| COUNTY | TYPE OF POLLUTANT | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Particulates | HCl | $SO_2$ and/or $H_2SO_4$ | Ethylene | Cumene | Oxidants | Lead | Herbicides | CS Gas | Deposits of Petroleum Products | Other |
| Allegheny | | | | | | 2 | | | | 2 | |
| Armstrong | | | 1,3,4,5,9,0,6,8 | | | | | | | | |
| Beaver | | | | | | | | 1,3 | | 1 | |
| Berks | | | 6 | | | | 1 | | | | 7 |
| Bucks (Del. Valley) | | | 7 | 7 | | 2 | | 7 | | | |
| Butler | 1,2,3 | | 4,0 | | | | | | | | |
| Cambria | 7 | | 4,6,0 | | | | | | | | |
| Carbon | | | 1,3,4,6,0,8,9 | | | | | | | | 1,3,4,6,0,8,9 |
| Centre | | | | | | | | | | 1,3,4,8,9,0 | |
| Chester | | | | | | | | | | | 7,8 |
| Clearfield | | | 6 | | | | | | | | |
| Columbia | 7 | | 7 | | | | | | | | |
| Elk | | | 3,4 | | | | | | | | |
| Indiana | | | 4,5,6 | | | | | | 1 | | |
| Jefferson | | | 5 | | | | | | | | |
| Lancaster | | | | | | 1 | | | | | |
| Lebanon | 6,7,9 | | | | | | | | | | |
| McKean | | 5,6 | | | | | | | | | |
| Mifflin | | | 6 | | | | 1 | | | | |
| Montgomery | | | 7 | 7 | | | | | | | |
| Philadelphia | | | 6,9 | | 3,6,8,9,0 | | | | | | |
| Susquehanna | | | | | | | | 8,9 | | | |
| Westmoreland | 6,8,9 | | | | | | | | | | |

* See Code For Affected Crops On Facing Page

Table 7. Direct Losses by Crop and Characteristic Pollutant Type

| CROP | TYPE OF POLLUTANT | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Particulates | HCl | $SO_2$ and/or $H_2SO_4$ | Ethylene | Cumene | Oxidants | Lead | Herbicides | CS Gas | Deposits of Petroleum Products | Other | TOTAL |
| | | | | | (Hundreds of Dollars) | | | | | | | |
| AGRONOMIC CROPS (commercial) | 33 | | 32 | | | 360 | 1640 | | 15 | 4 | | 2084 |
| VEGETABLES AND FRUITS (commercial) | | | 7 | | | 30008 | | | | | | 30015 |
| VEGETABLES AND FRUITS (non-commercial) | 3 | | | | 0.6 | | | | | | | 3.6 |
| TREES (Forest-Timber) (commercial) | | 200 | 194 | | | | | | | | | 394 |
| TREES (Christmas commercial) | | | 141 | | | | | | | | | 141 |
| TREES (Shade, Ornamental, Spoil Banks-non-commercial) | ?* | 1000 | 106 | | 27 | | | | | | | 1133** |
| FLOWERS AND FOLIAGE PLANTS (commercial) | 261 | | | 92 | | | | 140 | | | 72 | 565 |
| FLOWERS AND FOLIAGE PLANTS (non-commercial) | | | 0.2 | | 0.2 | 2 | | 0.5 | | | | 2.9 |
| LAWNS AND SHRUBS (non-commercial) | | | 1462 | | 25 | | | | | | | 1487 |
| TOTALS | 297 | 1200 | 1942 | 92 | 52.8 | 30370 | 1640 | 140.5 | 15 | 4 | 72 | 35825+ |

* Damage occurred, but was impossible to assess as aesthetics were involved.

Table 8. Direct Losses by County and Characteristic Pollutant Type

| COUNTY | TYPE OF POLLUTANT | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Particulates | HCl | $SO_2$ and/or $H_2SO_4$ | Ethylene | Cumene | Oxidants | Lead | Herbicides | CS Gas | Deposits of Petroleum Products | Other | TOTAL |
| | (Hundreds of Dollars) | | | | | | | | | | | |
| Allegheny | | | 12 | | | 10 | | | | ?* | | 22+* |
| Armstrong | | | 132 | | | | | | | | | 132 |
| Beaver | | | | | | | | | | 4 | | 4 |
| Berks | | | 25 | | | | 1040 | | | | ? | 1065+ |
| Bucks | | | ? | 5 | | 30,000 | | 140 | | | | 30145 |
| Butler | 15 | | 30 | | | | | | | | | 45 |
| Cambria | 11 | | 5 | | | | | | | | | 16 |
| Carbon | | | 1600 | | | | | | | | ? | 1600 |
| Centre | 18+ | | | | | | | | | ? | | 18+ |
| Chester | | | | | | | | | | | 72 | 72 |
| Clearfield | | | 3+ | | | | | | | | | 3+ |
| Columbia | 250 | | ? | | | | | | | | | 250+ |
| Elk | | | 2 | | | | | | | | | 2 |
| Indiana | | | 30 | | | | | | 15 | | | 45 |
| Jefferson | | | 23 | | | | | | | | | 23 |
| Lancaster | | | | | | 360 | | | | | | 360 |
| Lebanon | ? | | | | | | | | | | | ? |
| McKean | | 1200 | | | | | | | | | | 1200 |
| Mifflin | | | 0.5 | | | | 600 | | | | | 600.5 |
| Montgomery | | | 30 | 87 | | | | | | | | 117 |
| Philadelphia | | | 50 | | 53 | | | | | | | 103 |
| Susquehanna | | | | | | | | 0.5 | | | | 0.5 |
| Westmoreland | 3 | | | | | | | | | | | 3 |
| TOTALS | 297+ | 1200 | 1942 | 92 | 53 | 30370 | 1640 | 140.5 | 15 | 4+ | 72+ | 35,825+ |

* Damage occurred, but losses could not be determined.

Total indirect losses were estimated at 8 million dollars. Such losses include known grower profit losses and accounted for 7 million. This information was obtained from growers themselves. In some cases growers made production records available to the survey staff. Reforestation of denuded land was estimated at 1/2 million dollars based on area affected, topography, necessary site preparation, costs of plant material and planting. An additional 1/2 million was accounted for by grower relocation and crop substitution. Both direct and indirect losses in this report represent personal losses to growers.

Losses in aesthetic values, although not included in this report, are considered significant and were observed on several thousand acres. Home lawns and ornamentals were damaged to the extent that property values were probably reduced and many scenic hillsides and valleys are now scarred and bared. On many of these sites continuing pollution sources make it nearly impossible to re-establish vegetation. Several farms, productive in the past, are now abandoned as a result of air pollution.

Other indirect effects of pollution-caused vegetation damage were observed statewide. Some of these effects are stream silting, erosion, commercial and non-commercial land forced out of production, and changes of vegetation types on non-cultivated lands. In some areas the production of certain vegetable crops (spinach and certain lettuce varieties) has been discontinued. Although these effects probably contribute significantly to indirect costs, they were not included in this report because of the difficulty associated with their assessment.

## RESULTS OF SURVEY EVALUATION

Of 67 questionnaires distributed, 49 were completed and returned (73%). The following is a copy of the questionnaire. The numbers represent the percentages of responses that fall into either the "yes" or "no" categories based on the number of persons answering particular questions.

### STATEWIDE SURVEY PROJECT

Questionnaire

| Short Course | YES | NO |
|---|---|---|
| 1. Was the Introduction sufficient in outlining the purpose and objectives of the survey? | 100 | 0 |
| 2. Was the subject matter presented in each of the following topics too technical? | | |
| a) sources of air pollution | 12 | 88 |
| b) meteorological factors | 27 | 73 |
| c) effects of oxidants and similar symptoms | 38 | 62 |
| d) effects of particulates | 22 | 78 |
| e) problem of diagnosis | 22 | 78 |
| f) effects of fluorides and similar symptoms | 36 | 64 |
| g) effects of sulfur dioxide and similar symptoms | 27 | 73 |
| h) effects of minor pollutants and similar symptoms | 24 | 76 |
| i) methods of assessing damage | 7 | 93 |
| 3. Did you feel that adequate time was allotted for discussion? | 83 | 17 |
| 4. Were there too many slides shown? | 8 | 92 |

| | | |
|---|---|---|
| 5. Did the slides help you in understanding the type of injury described? | 89 | 11 |
| 6. Do you feel that the short course was the most efficient way of obtaining the information presented? | 91 | 9 |
| 7. Do you think a series of smaller conferences would have been more desirable? | 19 | 81 |
| 8. Do you feel that less formal presentation would have been more conducive to assimilation of information? | 93 | 7 |
| 9. Do you feel there should have been more exchange of ideas and discussion? | 73 | 27 |
| 10. Do you feel that the short course provided you with enough knowledge to diagnose air pollution problems? | 32 | 68 |
| 11. Do you see a need for future training workshops? | 86 | 14 |
| 12. Do you think one-day workshops or demonstrations held in different areas of the State would be worthwhile (for county agents in the area)? | 95 | 5 |

Survey

| | | |
|---|---|---|
| 13. Did you feel the survey was a worthwhile project: | | |
| a) before taking the course? | 63 | 37 |
| b) immediately after taking the course? | 98 | 2 |
| 14. Have you changed your opinion since then? | 13 | 87 |
| 15. Did you report any incidents? | 28 | 72 |
| 16. Were there any incidents you did not report for any reasons? | 17 | 83 |
| 17. Were reports you submitted investigated to your satisfaction? | 94 | 6 |
| 18. Was the public in your county aware of the survey? | 55 | 45 |
| 19. Do you feel efforts should be made to make the public aware of the survey? | 70 | 30 |

Handbook

| | | | |
|---|---|---|---|
| 20. | Was the handbook useful to you this summer in your work? | 73 | 27 |
| 21. | Should tables of relative sensitivity and resistance of various plant species to air pollutants have been included in the text? | 80 | 20 |
| 22. | Do you feel the material in the handbook is too technical? | 40 | 60 |
| 23. | Should the handbook be condensed further and made smaller in order to make it a better field manual? | 66 | 34 |

Communications

| | | | |
|---|---|---|---|
| 24. | Were the monthly summary reports adequate in keeping you informed? | 98 | 2 |
| 25. | Is the reporting card adequate in its present form? | 93 | 7 |
| 26. | Do we need a more rapid means of communication between your office and survey personnel? | 13 | 87 |
| 27. | Do you feel the results of the survey should be less publicized? | 8 | 92 |
| 28. | Do you feel the results of the survey should be publicized but without county identification? | 65 | 35 |
| 29. | Do you personally want to see the survey continued in its present form? | 97 | 3 |
| 30. | Do you want to see the survey continued, but without the involvement of county agents? | 14 | 86 |

The answers to questions 13 and 14 indicated that 88 percent of those responding to the questionnaire felt the survey was a worthwhile project. Most individuals (89%) were of the opinion that colored slides were quite helpful in recognizing pollution damage, but (93%) felt that less formal short-course presentations and field demonstrations (95%) would aid considerably. Answers to questions 29 and 30 imply that the survey should be continued (97%) and that county agents (86%) want to be a part of it. Apparently, only about half the Pennsylvania public (55%) was aware of the survey and about three fourths of the respondents indicated that the public should be made aware of the survey and the results should not be less publicized. More public awareness could have resulted in additional episodes reported.

## DISCUSSION

The data gathered in 1969 represent a first effort to obtain reliable information on a complex problem. It is of utmost importance to realize that no attempts were made to verify by tissue analyses that a suspected pollutant actually caused the damage. Identification of damage was based primarily on symptomatology. Furthermore, in certain cases it was extremely difficult to estimate the amount of permanent damage because reliable guidelines for determining such damages have not been developed. Estimates of losses reported here represent value judgments based on experience and the most recent crop value statistics. (See list of references). As survey personnel gain experience in recognizing damage and assessing losses, the quality of the estimate will improve. The results of this survey should not be interpreted as the final word in vegetation damage due to air pollution in Pennsylvania. The results do indicate, however, that air pollution is causing considerable crop losses in the State. A better understanding of how to collect such data has been realized and techniques for recognizing and evaluating vegetation damage due to pollution are being developed further to aid in obtaining reliable and useful information.

In future surveys an attempt will be made to document the cause of damage. Laboratory studies to establish guidelines for assessing damage are already in progress.

All damage figures contained in this report are based on visible damage, but from indications in the field, there are probably effects of pollutants on plants which cannot be determined visually.

It is relatively simple to distinguish between living and dead tissue as well as between "normal" and discolored tissue, but in several instances vegetation showed symptoms of reduced growth and low vigor near particular sources. Since the appearance of all vegetation of a certain type seemed similar in a given locality, there was no legitimate basis for comparison of plants on the same site experiencing the same microclimatic influences, i.e., the standard for comparison may have been a damaged plant. Controlled field studies are needed to determine such subtle effects of air pollution damage.

All information necessary to evaluate a given problem could not possibly be included on a simple reporting form such as that used in this survey. However, enough information can be included to indicate that a problem does exist and whether or not it deserves further investigation. It still remains the responsibility of those conducting the survey to investigate reports where pollution might be a problem until sufficient skill can be developed in others. It should not be expected that persons relatively unfamiliar with pollution damage be able to evaluate episodes themselves until more experience is gained. A continuing education and training program would certainly enhance the ability of field personnel to make on-the-spot evaluations of air pollution damage. However, it is imperative that diagnoses continue to be based on all available information, including comments and advice from professional people who are familiar with cultural practices and local environmental influences.

The information presented in this report is considered accurate, but conservative and data collected in the future may indicate that the 1969 estimates were much too low. This survey, as it was conducted in Pennsylvania, was the first of its kind in the United States. It should be viewed as a starting point from which to build. It is felt that the economic aspect of plant damage has been placed in the proper perspective with regard to its importance and the approximate magnitude of the losses incurred. As mentioned before, "guesstimates" of economic losses have been made in the past, many of which are perhaps unrealistic. The damage figures reported here are realistic and have been evaluated without emphasizing in a biased manner the importance or unimportance of the pollution situation.

One can readily see that the major air pollution effects on vegetation occur in southeastern Pennsylvania. This is the area in the State where agricultural crops are grown in greatest quantities and where soils and climate combined represent the greatest agricultural potential. Farmers are continuously being forced toward more intensive management practices in part because of competition for land for urbanization and industrialization. Crop monoculture, increased fertilization, and mechanization are more prevalent now than in any time in our history. Because of the future need to produce more crops on less land we must recognize and check those influences which reduce productivity.

In recent years much emphasis has been placed on dollar losses and human health effects associated with air pollution.

However, Pennsylvania's forested areas also contribute much to the well-being of the citizens because of the recreation provided and watersheds, both of which are vital factors in the development and growth of communities. Elimination of vegetation and changes in vegetation types can result in serious effects on wildlife, stream flow, and water quality. The economic effects of pollution in Pennsylvania presented in this report are only a measure of present costs. Equally important are the long term considerations involving indirect effects which have been mentioned briefly. The tourist and recreational income in Pennsylvania is significant, amounting to more than 3.5 billion dollars annually. Dollar values associated with recreation, aesthetics, fish and wildlife management, etc. are extremely difficult to establish and their intrinsic and extrinsic values are almost impossible to quantify.

As mentioned above, it is felt there are invisible effects of air pollutants on Pennsylvania's vegetation. It seems reasonable to suggest that there are probably reduced yields and less vigorous plants near certain pollution sources. In some cases vegetation is present, but does not really thrive even though there was no evidence of acute damage. In order to determine the magnitude of such effects, studies must be made under field conditions utilizing both ambient and filtered air. Differences in vigor, plant quality, and yields could be determined and conceivably new baselines established. At the same time, monitoring various levels of all pollutants present could provide valuable information for laboratory fumigation studies where the effects of individual and combined pollutants could be studied at concentrations at which plant "damage" occurred in the field. Until very recently, only various

concentrations of single pollutants have been associated with plant injury in laboratory chamber studies. Very few studies are presently being conducted on synergistic effects. We have very little insight into the combined effects of several pollutants as they affect plants in nature.

In the present survey, plant damage was evaluated by symptom expression of the receptor. However, there are several important pollutants such as heavy metals which, when present in concentrations usually observed near sources, induce no damage symptoms on vegetation. The presence of pollutants such as lead could be determined even though the plants exhibited no symptoms. Such a pollutant is very toxic to mammals and accumulates in animal tissues until the victim eventually dies from lead poisoning. Also, some pollutants elicit a response similar to other pollutants and the actual damage cannot be positively identified with respect to a specific pollutant. As a service to growers and to add accuracy to survey determinations, a phytotoxicology laboratory is essential. Analysis of plant tissues for the presence of stable pollutants and for their by-products could be made in such a laboratory.

Great progress is being made in the State in reducing industrial air pollution. However, the procedures are lengthy and a thorough knowledge and understanding of each pollution episode are necessary in order to solve the problems. Even though progress is being made we will have to live with the problem for some time. With this in mind, we should establish resistant forms of vegetation for areas where pollution will continue to be a problem. Some screening work has been done, but it is completely inadequate to enable us to cope with the problem until

a complete solution is attained. Large scale screening programs should be initiated to determine what forms of plant life (vegetables, ornamentals, trees, etc.) can best tolerate certain levels of individual pollutants and mixtures of pollutants as they are found in nature. Determining levels of single pollutants which induce plant injury in a controlled environment in the laboratory is not the ultimate solution. Plants should be screened for their sensitivity to the following individual pollutants and mixtures of these pollutants: $SO_2$, $H_2SO_4$, HCl, HF, $O_3$, $H_2S$, $NH_4$, and ethylene. These are considered the most important gaseous pollutants in Pennsylvania, but not necessarily in that order. Hydrogen sulfide and ammonia, although minor pollutants by themselves, may be very important when we consider synergism and potentiation.

Pennsylvania grows 20 thousand acres of cigar tobacco each year. Although not as valuable as southern varieties used for other products, ozone causes severe flecking on the most frequently planted variety, Penn-Pel, and it is thought to reduce the value of the affected leaves. Grading of Pennsylvania tobacco is not as strict as for other tobacco, but a reduction in grade from "wrapper" to "filler" material could mean a considerable economic loss. It should be determined if oxidant damage reduces the grade of leaves under various curing conditions. New, less sensitive varieties should also be developed for use near urban areas in particular.

Based on 1969 field activities, on the suspected amount of univestigated pollution damage, on the necessity for obtaining all the damage information each year, and on the results of the survey evaluation, it is believed that field activities in the years to come would yield

more valuable and precise information if the following recommendations are considered.

1. Three well-qualified field people (preferably plant pathologists) would be needed to cover the entire state in a systematic county-by-county survey in addition to investigating reports submitted by county agricultural agents and other agencies.

   Seventeen percent of those persons answering the questionnaire indicated that there were episodes of which they were aware, but which they did not report. It is understandable that situations arise which are very difficult to handle from a political standpoint and if reported, could result in ill feelings and possibly placing the employment of friends and other local people in jeopardy. For this reason independent investigations by CAES personnel are necessary to get all the data desired.

2. Field activities should be conducted from May 1 through September and greenhouse investigations should continue throughout the year.

3. Reliable estimates of damage by pollutant can best be obtained by coordinating efforts with the Pennsylvania Department of Health, Bureau of Air Pollution Control. The Regional Air Pollution Control Engineers have information regarding continuing sources, pollutants associated with specific processes, and those sources which have installed control devices. All industrial installations of a certain type should not be incriminated.

4. Informal training sessions with an abundance of good visual aids and field demonstrations should be conducted yearly.

5. News releases regarding the survey should be published in early April and again in mid July to obtain participation from the public.

6. Prompt reporting followed by prompt investigations are both essential if accurate appraisals of episodes are to be made.

7. When soliciting the field experience and aid of county agricultural agents, emphasis at first should be placed on their recognizing that a pollution problem might exist, and eventually on their evaluating the episodes themselves.

In future surveys there should be a common basis for estimating losses. Although direct losses covered in this survey do not include grower profits since they cannot be claimed in most damage suits, normal profits nevertheless must be included in total losses and probably should be considered in litigation procedures. The following guidelines for studying economic effects of air pollution on agriculture have been prepared by Dr. Hays B. Gamble, resource economist with the Institute for Research on Land and Water Resources at the Pennsylvania State University. These guidelines are suggested for consideration when relating the effects of air pollution to the regional and national economy.

## SOME IMPORTANT ECONOMIC CONSIDERATIONS OF AIR POLLUTION DAMAGE TO CROPS OR PLANTS

The following resume focuses on some of the important points that must be observed when assessments are made of air pollution damages to crops and plants. No attempt is made here to address the problems encountered in assessing other forms of pollution damages, particularly those undesirable effects involving nonmarket or social costs. Three main levels of aggregation are dealt with in this analysis: crop damage to individual farms; regional crop damages; and crop damages at the national level. Seldom are the damages at the separate levels additive.

I. Damage to an individual farmer or grower.

A. For a farmer or grower experiencing damage to his plants, the cost of air pollution <u>to him</u> is the difference in the returns to all factor inputs under polluted conditions as compared to what these returns would be in the absence of pollution.

1. If a farmer makes no changes in the mix or quantity of his inputs, or kinds of outputs, and all factor and product prices remain constant, his costs would be the market value of his crops lost to pollution.

2. If the farm or enterprise goes out of business as a result of air pollution, then the loss or gain to the farmer is the difference between the total returns to all factor inputs employed at the time of pollution and the returns to these same factor inputs employed in an alternative manner after adjustment. The cost of air pollution is <u>not</u> the total value of farm output foregone.

3. If the farmer changes the nature of his enterprise (new crops or other products and/or changes in the input mix in response to pollution damage) then an approximate measure of pollution damages to him is the difference in the returns to all factor inputs under polluted conditions as compared to the returns to his factor inputs following his adjustment. There may be gains to the farmer if, prior to pollution he was not employing his resources to their maximum economic efficiency.

II. Crop damages at the regional level.

A. Direct regional costs.

1. For farmers or growers experiencing damage to crops, the cost of air pollution to them is the difference in the collective returns to all factor inputs under polluted conditions as compared to what these returns would be in the absence of pollution. There may be regional gains as well as losses.

2. If farms go out of business as a result of air pollution, then the losses or gains to the region are the difference between the total returns to all factor inputs employed on these farms prior to pollution and the returns to these same factor inputs reemployed in the region in an alternative manner. Returns to factors reemployed outside the region should not be counted.

B. Indirect regional costs.

In addition to the gains or losses experienced directly by farmers and growers suffering from air pollution, account must also be taken of indirect regional gains or losses to other firms and individuals in the region. These will come about as a result of:

1. Other producers in the region increasing their output or responding in some other way to a change in market supply. What is one man's loss is another man's gain. Increases in output on nonpolluted farms must be accounted for.

2. Firms and individuals in the region dealing directly or indirectly with the farmer or grower altering their employment of certain factor inputs in response to the farmer's adjustments to pollution damage. The collective net factor returns after adjustment as compared to the net factor returns prior to adjustment for these indirect firms will approximate their regional gains or losses from air pollution.

III. Crop damage costs at the national level.

A. The gains or losses as a result of air pollution at the national level will be the same as those at the regional level <u>only if</u>:

1. None of the factor inputs displaced by pollution are reemployed outside a given region.

2. All indirect gains and losses are accounted for by firms and individuals within a given region.

B. If factor inputs displaced as a result of pollution are reemployed outside the region, there would most likely be a regional loss but there may or may not be a loss at the national level. Comparison of net returns to factor inputs at the time of pollution and in their alternative employment, regardless of regional setting, will indicate the magnitude of gains or losses at the national level. Only if, at the time of pollution, all factors were employed at their maximum level of economic efficiency under purely competitive factor and product markets could it be unequivocally claimed that a loss would occur at the national level.

C. Indirect gains or losses at the national level must also be taken into account.

1. Crop output in one region may increase in response to a decrease in output in another region as a result of pollution damage. There may be virtually no appreciable difference in net gains or losses at the national level while significant differences may exist at the regional level.

2. Firms and individuals dealing directly or indirectly with growers suffering pollution damage may adjust their factor inputs and product outputs in response to grower adjustments. National gains or losses will not be the sum of regional gains or losses under such conditions. Rather, the nation should be viewed as a single region, with net returns to all factor inputs in affected firms and individuals considered simultaneously.

The above analysis does not take into consideration any changes in income distribution, either within a regional setting or nationally, and makes no judgment as to changes in the welfare of individuals or to the collective society.

Plate I. Injury to cucumber from cumene (isopropyl benzene) spill near a chemical plant.

Plate II. Sulfur dioxide injury to alfalfa near a coal-fired power plant.

*Plate I*

*Plate II*

Plate III. Injury to beans, okra, and tomatoes from cumene (isopropyl benzene) spill near a chemical plant.

Plate IV. Limestone dust accumulation (bottom) on Norway spruce near a quarry.

*Plate III*

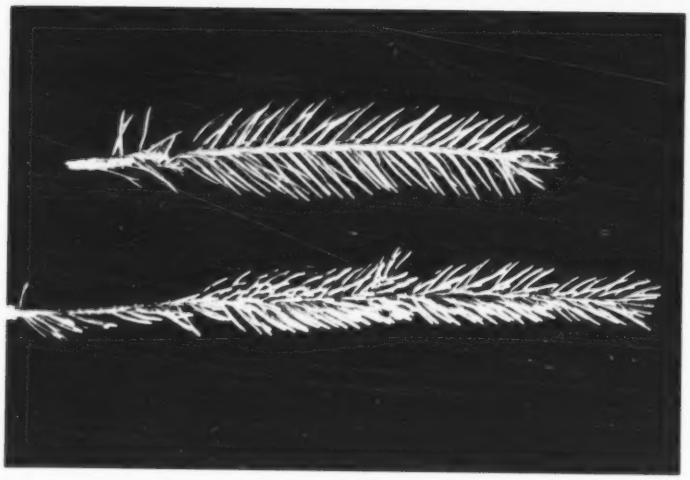

*Plate IV*

Plate V. Damage to forest trees caused by smoke from open burning of plastic materials.

Plate VI. Oxidant injury to tobacco, variety Penn-Bel, near urban-industrial area.

Plate V

Plate VI

Plate VII. Erosion on a hillside denuded by fumes from a smelter.

Plate VIII. Erosion on a mountainside denuded by fumes from a smelter.

Plate VII

Plate VIII

## SUMMARY

A statewide survey of vegetation damage caused by air pollution was initiated to determine the losses on food, fiber, and ornamental crops in Pennsylvania. The assistance of the Cooperative Extension personnel (county agricultural agents and extension specialists) was enlisted to provide the specialized manpower needed for complete coverage of the State. A 3-day short course was held to acquaint participants with sources of air pollution, dispersion, diagnosis, recognition of symptoms, and methods of assessing damage. A handbook containing color illustrations of typical damage and guidelines in diagnosing injury was prepared and distributed to all participants.

A reporting form was printed on a self-addressed, postage-paid post card and copies were provided to each participant. A post-doctoral scholar in plant pathology was appointed to investigate each report. Monthly progress reports and a comprehensive summary of findings were prepared and distributed to all personnel and agencies involved. Upon completion of field activities, county agents were requested to evaluate training and survey methods, field investigations, and communication.

Ninety-two investigations were made in 28 counties. We are aware of air pollution damage which was not reported and other incidents which we were unable to follow up in detail. These have not been included. Most reported incidents occurred in areas of greatest agricultural activity. Greatest economic losses were observed on vegetable, fruit, and agronomic crops, followed by lawns, ornamentals, greenhouse flowers, and forest trees.

The suspected major pollutants in decreasing order of importance are: oxidants, oxides of sulfur, lead, hydrogen chloride, particulates, herbicides, and ethylene.

Direct economic losses exclusive of profits were estimated to be in excess of 3.5 million dollars. Indirect economic losses were estimated to account for an additional 8 million dollars. Indirect losses include grower profits, crop substitution, relocation costs, and reforestation of denuded land. In addition, other indirect losses were observed, but could not be quantified. These include changes in vegetation type, erosion, stream silting, decrease in water retention capacities of watersheds, aesthetic losses, and farm abandonment.

# REFERENCES

Forest Industries Statistics. Pennsylvania Department of Commerce, Harrisburg, Pennsylvania. 1967.

Handbook of Effects Assessment: Vegetation Damage. Edited by N. L. Lacasse and W. J. Moroz. Center for Air Environment Studies, The Pennsylvania State University, University Park, Pennsylvania. 1969.

Pennsylvania Crops and Livestock Annual Summary. Pennsylvania Crop Reporting Service, Pennsylvania Department of Agriculture, Harrisburg, Pennsylvania. 1968.

and advanced undergraduates of many disciplines and representatives of air pollution control agencies at the local, state, and federal level.

The Air Pollution Specialist Training Program is an intensive course designed to provide specialized knowledge and skills necessary for work in air pollution control instrumentation for field monitoring and sampling. The program involves one term of full time work on campus for students who have completed at least one year in their studies for an associate degree in engineering technology. Also initiated under this program is a Pennsylvania survey of vegetation damage. Agricultural extension personnel and county agents were trained to recognize air pollution damage to crops and are now reporting damage seen in their daily work to the Center for analysis.

Address requests for more information concerning the training programs to the Director, Center for Air Environment Studies, The Pennsylvania State University, University Park, Pennsylvania 16802.

## Publications Available

AIR POLLUTION TITLES, a current awareness publication service, is available on a January-December subscription basis. This publication is a quick guide to current literature and has some capacity as a retrospective searching tool. APT uses a computer-produced, Keyword-in-Context (KWIC) format to provide a survey of current air pollution and related literature. During the year over 1,000 journals are scanned for pertinent citations.

Subscriptions to APT at $15/year, cover six issues per year as follows: No. 1, January-February; No. 2, March-April; No. 3, May-June; No. 4, July-August; No. 5, September-October; No. 6, cumulative issue for the year, including November-December citations.

The 1969 subscription of APT is now available. Complete subscriptions for 1966, 1967, and 1968 are out of supply. However, cumulative issues for 1966, 1967, and 1968 are being issued; the cost is $10. each.

INDEX TO AIR POLLUTION RESEARCH, an annual publication, includes government sponsored research in the air pollution field and the results of a survey of air pollution research projects being conducted by the industrial, sustaining, and corporate members of the Air Pollution Control Association and the American Industrial Hygiene Association, and research supported by other industries and non-profit organizations.

The Index utilizes the Keyword-in-Context (KWIC) format for rapid scanning of project titles. In addition, this publication provides a complete bibliography including mailing addresses where additional information about the project may be obtained. Beginning with the 1967 edition, a section containing citations of papers resulting from the research in progress is included.

Copies of the 1966 and 1967 editions are available at $1.25 each. The 1968 edition costs $2. Requests for additional information and orders should be addressed to: Information Services, Center for Air Environment Studies, University Park, Pennsylvania 16802.

NOTE: The National Air Pollution Control Administration of the United States Public Health Service has contracted the Center for Air Environment Studies to prepare A Guide to Air Pollution Research which will parallel and replace the 1969 Index. By contract agreement, the National Administration will manage the distribution of all copies. The Guide will be available in 1970.